Fishermen's perceptions of coastal fisheries management regulations: Key factors to rebuilding coastal fishery resources in Taiwan

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ABSTRACT

Although Taiwan has taken conservation measures for coastal and offshore fishery resources in recent years, the effectiveness of resources rebuilding is unclear. Many initiatives, such as marine protected areas (MPAs), are frequently opposed by fishermen. This research reviewed management measures and interviewed 313 fishermen by purposive stratification and snowball sampling. Data were analyzed by fishery, age, and vessel size to address the attitudes and perceptions of fishermen toward twelve fisheries management measures. Descriptive statistics, as well as chi-squared tests and independent t-tests, were used for basic analysis and differences comparison between groups. The results showed that illegal fishing vessels from China (71%), overfishing (69.5%), and ghost fishing (64%) are considered as major threats to Taiwan marine resources. The measures from voyage data recorders, larval anchovy, precious coral, and shark management result in higher satisfaction because of strict monitoring. The satisfaction measures for three net-type measures, i.e., trawler area closure, torch-light limitation, and gillnet limitation, were low. Line-type and small-scale vessel fishermen are more concerned with "small mesh size" and "ghost fishing". Net-type, large-scale vessels and young fishermen were concerned about "climate change" and "inappropriate measures". In conclusion, the priorities are to (1) establish a comprehensive scientific research framework; (2) strengthen enforcement to ensure resources rebuilding, especially for large-scale net fisheries; (3) promote public awareness and build communication between stakeholders to obtain support; and (4) communicate among policymakers and fishermen to increase mutual understanding.

1. Introduction

Fisheries are not only an important protein source for humans; they also hold irreplaceable value to local communities by providing job opportunities and culture cultivation. Fishery management measures are increasing as fishery resources have been threatened by overfishing, illegal fishing and other human impacts (Agnew et al., 2009; Parsons et al., 2014). The fishermen's knowledge of fish species, ecology, and habits can be helpful to fishery management (Silvano and Valbo-Jørgensen, 2008). The failure of marine resource governance may be due to a lack of respect of fishery management measures and poor knowledge of resource users, intensifying the need to assess the attitudes of stakeholders affected by management strategies (Dimech et al., 2009; Jagers et al., 2012; Pérez-Sánchez and Muir, 2003; Silva and Lopes, 2015; Villasante et al., 2016). To find the answer as to why management regulations are not being followed or respected could help to avoid overfishing, stock decimation, environmental degradation, economic losses and community failure (Jagers et al., 2012). In

addition, knowing the perception among different groups of fishermen allows gaining knowledge of their opinions as to how to reduce the conflict (Bruckmeier et al., 2005; Garza-Gil et al., 2015; Karper and Lopes, 2014; Silva and Lopes, 2015).

Taiwan is located in the Pacific Ocean and has rich marine biodiversity and is a habitat for marine resources. The three major currents are the Kuroshio Current, passing to the east of Taiwan, the Taiwan Strait Current in the west, and the China Coastal Current flowing southward from China. As the three currents meet during seasonal change, they bring abundant nutrients and biodiversity into the area, especially to northern Taiwan (Fig. 1).

Taiwan has developed its coastal and offshore fisheries since the 1950s; the highest production was achieved in the 1980s, with annual production in the 400 thousand ton range, but has decreased gradually in the following three decades (Fisheries Agency, 2002). Although its marine capture production was in the top 20 in the world (FAO, 2016), only 16% was from coastal and offshore fisheries in 2015 and 24% in 2017 (Fisheries Agency, 2018). The production of coastal and offshore

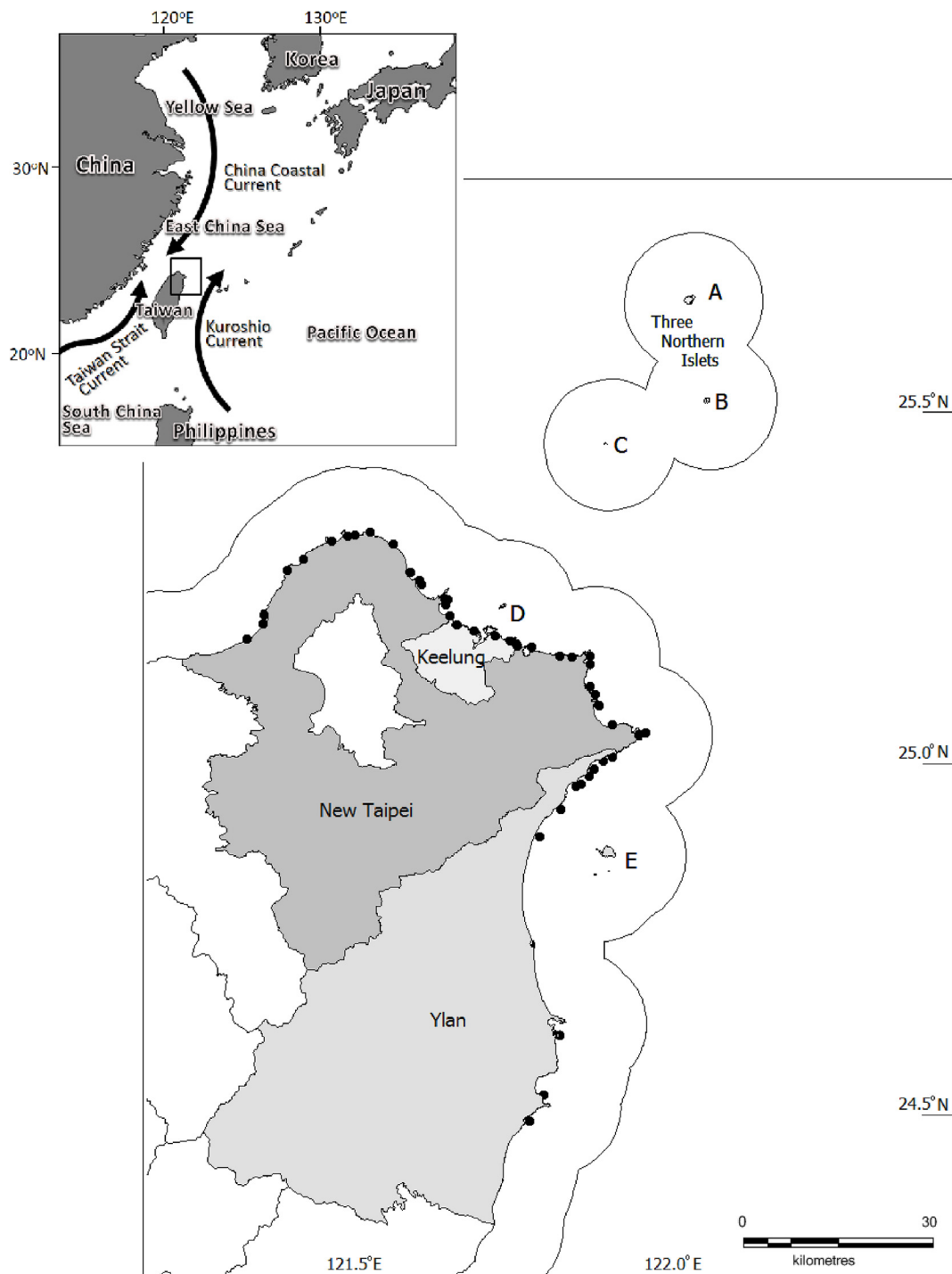**Fig. 1.** Map of the islands and ports in northern Taiwan. Study area in Taiwan's northeast waters, including five islands in three northern counties (New Taipei, Keelung and Yilan). A: Agincourt islet; B: Pinnacle islet; C: Crag islet; D: Keelung islet; E: Turtle island. The black spots are fishing ports.

fisheries dropped to approximately 185 thousand metric tons, valued at approximately US$ 576 million in 2017 (Fisheries Agency, 2018). The historical production of coastal and offshore fisheries is shown in Fig. 2. At least fourteen types of fishing gear are used, including line-type fisheries (pole-and-line, pelagic longline, bottom longline, trolling, etc.), net-type fisheries (trawl, Taiwanese purse seiners, torch-light, gillnet, set net, crab pots, stick-held net, precious coral trawler, etc.), and others (eel fry, flying fish roe) (Fisheries Agency, 2018). More than half of the coastal production comes from mackerel purse seiner (47%). Others include trawler (19%), tuna longline (8%), gillnet (5%), set net (4%), and torch-light net (4%) in 2017 (pie chart in Fig. 2) (Fisheries

Agency, 2018).

After a long period of overexploitation, expanding efforts to rebuild fisheries are underway. Several coastal and offshore fishery management measures were adopted in the recent decade, which included fishing capacity limitation (Huang and Chuang, 2010), total allowable catch (TAC), area closure, gear limitation, individual quota (IQ), fishing season limitation, size limitation and enhanced fishery data collection (Chen, 2012; Huang et al., 2016). However, there were many fishermen protests when the fishery authority discussed new proposed conservation measures. For example, the discussion of marine protected areas (MPAs) in northern Taiwan stagnated for almost a decade (CPAMI,
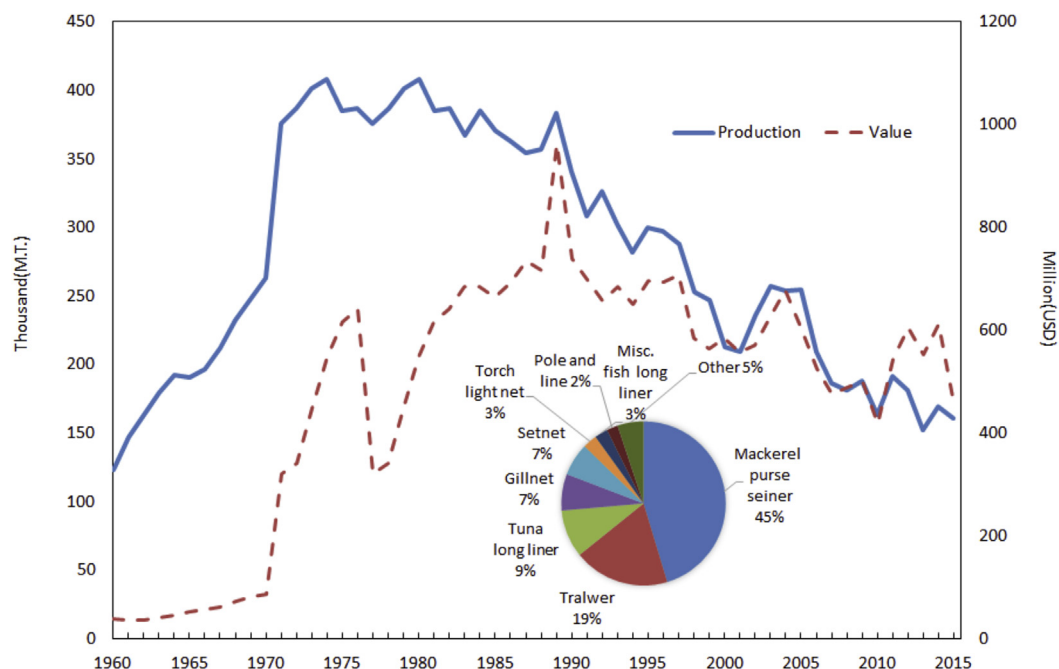
Fig. 2. The historical catch and value of Taiwan coastal and offshore marine capture fisheries from 1960 to 2017. The percentages in the pie chart are the compositions of the catches by fisheries in 2017. Data source: Fisheries Agency (2018).

2008). Closure-areas for trawlers (Shu, 2014) and TACs for mackerels were rejected by local fishermen (Lin 2013a,b).

There were studies that indicated that fishermen's perceptions and attitudes would help policy makers improve their understanding of management effectiveness, such as the preferences of different fishery policies and certain impacts (Gelcich et al., 2009; Pierce and Mozumder, 2014; Pita et al., 2010; Rodwell et al., 2014), performance of MPAs (Dimech et al., 2009; Leleu et al.et al., 2012; Silva and Lopes, 2015; Suman et al., 1999), and fishery conflicts (Bennett and Dearden, 2014; Dimech et al., 2009).

Taiwanese fishermen have a positive view toward resource use. Management by fishermen enhanced the intention of other fishermen to participate in management, whereas incentives in the form of a reward did not seem strong enough to sufficiently draw fishermen's participation (Chen, 2010). Huang and Ou (2010) suggested that a long-term strategy worth implementing in Taiwan's coral fisheries management is bottom-up management, to allow producer organizations more power in catch quotas and supply-demand policies through self-governance. However, because the coastal and offshore fishery management regulations were only established in the past decade, no previous research has dealt with the problems associated with the coastal and offshore fisherman perceptions toward the regulations and marine resources from an integrated perspective. Considering that there was a lack of a systematic review of Taiwanese fisheries conservation measures and fishermen's perceptions, the objectives of this research are to (1) review the fisheries management system of Taiwan, (2) understand the perception and attitude of fishermen to conservation measures, (3) analyze the perceptions between different groups of fishermen, and (4) provide suggestions for conservation actions and priorities.

2. Materials and methods

2.1. Study area and fisheries

In 2017, there were 11,198 powered vessels in coastal and offshore waters (Fisheries Agency, 2018). There are 40 fishing ports with 4314 fishing vessels, including crab pots, gillnetters, longline, mackerel purse seiner, pole and line, torch-light net, and trawlers fishery in three

northern counties (New Taipei, Keelung, and Yilan) (Fig. 1) (Fisheries Agency, 2002). The overall catches of these three counties reached 102,320 mt, and landing values reached 245 million USD, which was 63.8% and 53.7% of Taiwan's catch yield and landing value, respectively. The study was conducted in major fishing ports.

2.2. Review of Taiwan's coastal and offshore fisheries regulations

Considering the limitations of marine resources, the government adopted a limit-entry system for all fishing vessels beginning in 1991 (Huang and Chuang, 2010). In addition, to reduce overcapacity, the vessel owners are encouraged to undergo voluntary cessation for at least ninety days per year, with the government granting a subsidy. In 2015, there were 10,251 vessels that applied for the voluntary cessation in exchange for 6 million USD in total (Fisheries Agency, 2016a).
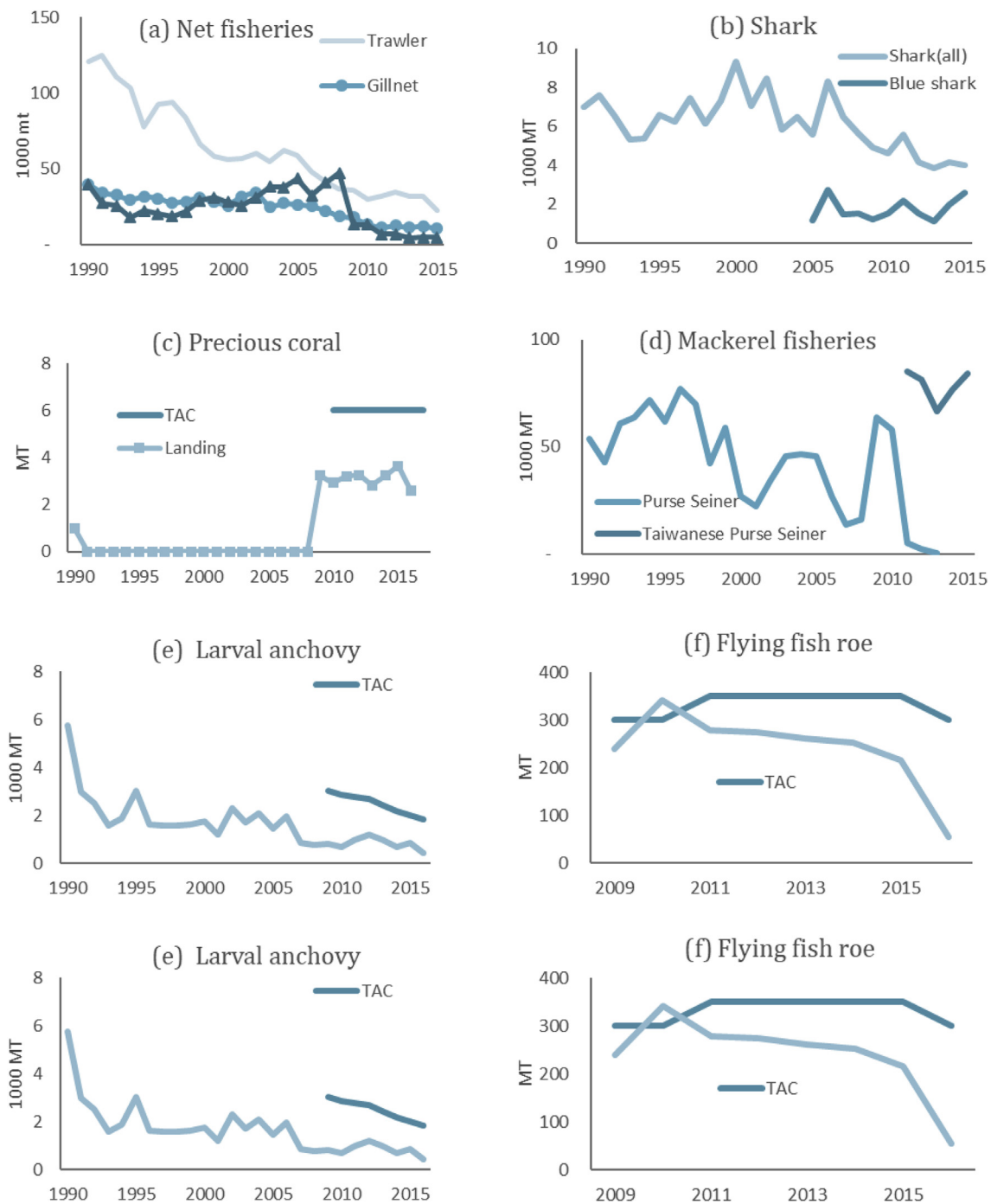
For monitoring purposes, vessel monitoring systems (VMS) have been used on large/high seas fishing vessels since the late 1990s (Chang, 2011). Furthermore, voyage data recorders (VDR) have been used on coastal and offshore vessels since 2007 (Council of Agriculture, 2007). In 2015, 2260 vessels had installed VMS (Fisheries Agency, 2016a) and approximately 5000 vessels had installed VDRs.

The MPA system in Taiwan is complicated and can be traced to 1978. Many fishery resources conservation areas have been demarcated, for example, those of abalones, lobsters, hard clams, purple clam, sea urchins, agar, mud shrimp, horseshoe crab, and trochus (Fisheries Agency, 2016b). There are twenty-eight fishery resources conservation areas, with a total 5362 ha protected by the Fisheries Act. During the development of public conservation awareness, more types of MPAs have been demarcated by different targets and authorities, which include abundant biodiversity resources, important aquatic resource conservation zones, special landscape resources and recreational zones, important underwater cultural heritage zones and special natural landforms. The fishery authority defined the categories of MPAs into three major types: no-entry or no-impact (589 km^2 that covers 0.9% of 12 total nautical miles (nm)), no-take (4.6% of 12 nm) and multi-function (42.07% of 12 nm) in 2012 (Fisheries Agency, 2016b). However, despite the long history of MPAs, there is a limited databank and limited monitoring systems and quantitative data for target species to

Table 1
Summary of major Taiwan coastal and offshore fisheries management regulations.

Type	Fishery	Year	Restricted areas	Species/size limit	Seasonal closure	TAC	IQ	Data	Regulations detail
Net	Trawler	1999	V						- Banned within 3 nm from coast for all trawlers - Banned within 12 nm for large trawlers (> 50 GRT)
	Gillnet	2001	V						- Banned with 3 nm in five counties (Taitung since 2001, Pintung for Liuchiu Island since 2013, Tainun since 2012, New Taipei 2012 and Keelung since 2005, but mostly are parts region but not all) - For vessel less than 100 GRT, the length of nets shall less than 2.5 km
	Torch-light	2003	V						- Banned within 12 nm in Pintung - 6 nm in four counties (Taitung, Penhu, Huilan, Tainan) - 3 nm in Ilan - 6 nm, excluded May 1 to Aug 31 - 2000 W for 3 nm for Muaili
Specific species	Shark fishery	2005		10 species sharks and rays					- Prohibited species: whale shark, oceanic whitetip shark and silky shark in the Pacific Ocean - Mandatory report for white shark, basking-shark and megamouth shark - Shark's fins naturally attached for coastal fisheries
	Precious corals fishery	2008	Only in five specific areas			6 mt in 2016	200 kg/v	logbook	- Mandatory VMS - Exit and entry at designated ports prior application - Inspection at time of port entry, monitoring of offloading and auction of catch - Receiving of at-sea observers - Boarding and inspection at sea
	Taiwanese mackerel purse seiner	2013	V		June 1- June 30				- Banned 6 nm for all and 12 nm for vessel larger than 100GRT - Mandatory VMS and Daily catch logbooks. - Landing at designated fishing ports, with the entire catch weighed.
Spawning and juvenile	Larval anchovy fishery	2009	Ban within 500 m from coast		three months	1826 mt in 2016		logbook	- Cross-county/city fishing is prohibited - Review annually - Three consecutive months closure during May 1 to September 15
	Flying fish roe fishery	2011				300 mt in 2016		logbook	- Exit and entry at designated ports prior application and inspection at time of port entry, monitoring of offloading and auction of catch - Receiving of at-sea observers and acceptance of boarding and inspection at sea - Operating in areas of intertidal terrains and estuaries, no licenses necessary
	Eel fry fishery	2013			March 1-October 31				
	Crab fishery	2014		Size limit for five species					- Ban on *Portunus sanguinolentus*, *Charybdis feriatus*, and *Portunus pelagicus* with carapace width under 8 cm - Ban on *Charybdis natator* and *Ranina* with carapace width less than 6 cm - Banned of egg carrying female between August 16 to November 15

Source: Fisheries Agency (2016b).

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Fig. 3. Recent catch and total allowable catch of major management fisheries. (a) Net fisheries, (b) Shark fisheries. The catch of blue shark is separated from sharks since 2005. (c) Previous coral, (d) Mackerels, (e) Larval anchovy fisheries, (f) Flying fish roe. The catch is estimated since 2009, (g) Eel fry fisheries, (h) Crab fisheries, including the catch from crab pots and trawlers. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

prove the success or failure of MPAs in Taiwan (Huang et al., 2016; Wen and Chen, 2014).

In addition, there are ten major fishery management regulations for coastal and offshore fisheries, summarized in Table 1. Based on the Fisheries Act, if fishermen violate these regulations, the fine ranges from 1000 to 5000 USD. If the violation is serious, the fishing license or the captain/crew's licenses shall be suspended or revoked. Those ten measures can be categorized into the following three types: area closure for net-type fisheries, conservation for specific species, and conservation for juveniles and spawning stocks. Catch trends are shown in Fig. 3.

2.2.1. Type I area-closure for net-fisheries

The trawler is an important fishery method that has been developed since the 1960s. The number of trawlers was 1379 in 2015. It is prohibited for all trawlers to fish within 3 nm of the coast and within 12 nm for trawlers larger than 50 GRT (Council of Agriculture, 1999).

Gill net fishery can be classified into single layer and multilayer nets (two-four) from surface to bottom. There were 1629 powered craft and 7157 raft gillnets (approximately 38% of total vessels). Since gillnets might impact marine environments, five county governments set closed areas within 3 nm and banned multilayer gillnets beginning in 2005.

The swordtip squid (*Uroteuthis edulis*) is a major target species in

northeast Taiwan (Wang et al., 2008) for torch-light nets. The main limitation of torch-light fishery is that it is not allowed to operate within 3 nm of the coast, and the power of the attracting fish lamp must be less than 5 kW.

In short, the measures for trawlers are applied in the entirety of Taiwan coastal waters. Gillnet and torch-light fisheries are applied in some counties. The catches of trawl, gillnet and torch-light have declined slightly in the last twenty years (Fig. 3a).

2.2.2. Type II managed for specific species

Shark production was 4023 mt in coastal and offshore water and 17,766 mt in distant water fisheries in 2015. The blue shark (*Prionace glauca*) was the major species, comprising between 20% and 60% of sharks caught (Fig. 3b). Shark finning was banned beginning in 2005. Several shark species have been banned in accordance with the conservation recommendations adopted by regional fisheries management organizations. A mandatory reporting system for great white shark (*Carcharodon carcharias*), basking-shark (*Cetorhinus maximus*) and megamouth shark (*Megachasma pelagios*) has been requested (Liu, 2015).

Precious coral fisheries are of high value and are controversial due to their impacts on the marine environment. Although it was closed in the 1990s, there were some vessels operating illegally. The Fisheries Agency decided to reopen it with strict regulations in 2008. The capacity limitation (limited to 60 licensed vessels), TAC (6 mt), individual quota (200 kg per vessel) and fishing grounds limitations are applied (Chen, 2012; Fisheries Agency, 2016b). The number of fishing vessels and the catches of precious coral fishery are strictly controlled, and the catch was stable in recent years (Fig. 3c).

Mackerel purse seiners were introduced from Japan and targeted spotted mackerel (*Scomber australasicus*), pacific mackerel (*Scomber japonicus*) and Japanese horse mackerel (*Trachurus japonicas)* in the late 1970s. The production was highest, at 77,000 mt, in 1996. However, the number of mackerel purse seiners decreased from 8 groups in 1989 to zero in 2012 due to high manpower and safety issues. Taiwanese mackerel purse seiners were developed from the concept of the torch-light net since 2001 (Lee et al., 2006) and have replaced Japanese-style purse seiners (Fig. 3d). Lee et al. (2013) showed that the catch per unit effort (CPUE) of spotted mackerel has declined for years. Mackerel purse seiner management measures **were** adopted in 2013 with time closure in June and area limitation for large Taiwanese purse seiners (Fisheries Agency, 2016b).

2.2.3. Type III conservation for juvenile and spawning stock

Larval anchovy fisheries developed in the 1960s. Production achieved 10,000 mt in the 1970s and dropped to 825 mt in 2015. The target species are *Encrasicholina puntifer*, *E. heteroloba*, and *Engraulis japonicas*. The first management measures started in 1999. The TAC is decided annually according to recent stock assessment, which was 3021 mt in 2009, with a 500 m closure-area from the coast and with a 3 months minimum closed-season (Fisheries Agency, 2016b). However, the TAC decreased to 1826 mt in 2016 (Fig. 3e). A recent resource assessment showed the slow recovery of stocks, although it is still much lower than 1980s levels (Chen et al., 2016). It is suggested that those management measures should remain and be strictly monitored (Chen et al., 2016; Huang et al., 2016).

Flying fish roe fisheries formally began in 1987. Flying fish roe fishery management measures began in 2007 with TAC and landing monitoring (Fisheries Agency, 2016b; Huang and Ou, 2012). The TAC was 350 mt in 2012 and decreased to 300 mt in 2016 (Fig. 3f). The average (2011–2015) production was 259 mt (Fisheries Agency, 2002).

Eel fry fishery is one of the most important export industries with high economic value. Japanese eel (*Anguilla japonica*) and giant mottled eel (*Anguilla marmorata*) covered 95% of the total catch. Glass eels are collected from coastal waters. The fishing season is from November to February for Japanese eel and year-round for giant mottled eel (Shiau

et al., 2014). The eel fry fishery management measures were set in 2013. The closed season was set from March 1 to October 31 (Fisheries Agency, 2016b). The catch fluctuated in the past ten years (Fig. 3g).

Crabs can be caught by trawler and gillnet but are mostly caught by crab pots throughout the year. The targeted species include *Charybdis feriatus, Portunus sanguinolentus, Portunus pelagicus, Charybdis natator*, and *Ranina* (Tzeng, 2015). The catch decreased after 2005 (Fig. 3h). The size limitation was set in 2014, which prohibited catching *Portunus sanguinolentus, Charybdis feriatus,* and *Portunus pelagicus* with a carapace width under 8 cm, and *Charybdis natator* and *Ranina* with a carapace width under 6 cm. In addition, during the peak spawning season (August 16 to 15 November 15), catching female crabs carrying eggs became prohibited (Fisheries Agency, 2014).

2.3. Sampling and questionnaire design

Purposive stratification and snowball sampling were used not only because fishermen are hard to reach (Goodman, 2011) but also for a comparison of the perceptions of different fisheries, fishermen from different fisheries, ages, and vessel size. The tentative sample size was 353 to ensure the 95% confidence level and 5% confidence interval from 4314 vessels in the research area (Fisheries Agency, 2016a).

To meet the research objectives, qualitative and quantitative research questions were designed for the semi-structured questionnaire. The final quantitative portion was adopted after a pre-test was administered to 13 fishermen in July August 2015. There were four parts in the final questionnaire. The first part was the respondent's demographic information (age, education, experience). The second part included fishing activities (level of dependence on fisheries, gear, target species, fishing efforts). The third part focused on the attitude regarding the current marine resources issue, such as those reasons that might cause negative impacts to fishery resources, including introduced species, bycatch, climate change, ghost fishing, habitat destruction, inappropriate or ineffective management measure, IUU (illegal, unreported, unregulated) fishing, law enforcement, marine debris, marine engineering, marine pollution, overfishing, and small fishing net mesh (Baulch and Perry, 2014; Bax et al., 2003; Bilkovic et al., 2014; Coleman and Williams, 2002; Davies et al., 2009; Hoegh-Guldberg et al., 2007; Hong et al., 2013; Kumar and Deepthi, 2006; Parsons et al., 2014; Shahidul Islam and Tanaka, 2004; Tacon and Metian, 2008). "Illegal fishing vessels from mainland China" was added due to suggestions during the pretest interview. A 5-point Likert scale (1 = strongly disagree, 5 = strongly agree) was used.

The success of fishery management measures are predicated on positive fishermen perceptions of socioeconomic and ecological outcomes in many cases, which include the perceptions of the effectiveness and quality of management and governance policies, institutions, and processes (Lockwood, 2010; Bennett and Dearden, 2014). In the fourth part, fishermen were asked about their perception of satisfaction, effectiveness and enforcement/compliance level with twelve major fishery management measures. A 5-point scale was used in section (1 = low satisfaction, 5 = high satisfaction). Furthermore, all the interviewees were asked the general suggestion of the coastal and offshore fishery management and the additional responses of conservation attitude and feelings about fishery resource changes were recorded.

2.4. Data analysis

Descriptive statistics are used for background analysis. To understand the perceived difference among fishermen, the respondents were classified into three groups according to their age (younger: up to 45-year-old, older: over 45-year-old), the size of fishing vessel (small vessel: below 50 GRT, large vessel: over 50 GRT) and fisheries gear (net fisheries or line fisheries). Differences between groups were tested with chi-squared tests and independent t-tests (Silva and Lopes, 2015). The data were analyzed with SPSS (IBM SPSS Statistic 19).

Table 2
Demographic data of interviewed fishermen.

Age	N	%	Education	N	%	Experience (year)	N	%	Position	N	%
18–24	12	3.8%	Not attending	4	1.3%	≤1	7	2.2	Captain	260	83.1
25–34	15	4.8%	Primary School	67	21.4%	1–10	48	15.3	Crew	34	10.9
35–44	61	19.5%	Junior High School	134	42.8%	11–20	32	10.2	Owner	6	1.9
45–54	97	31.0%	Senior High School	69	22.0%	> 20	224	71.6	Swain	9	2.9
55–64	82	26.2%	University	22	7.0%				Other	1	0.3
≥65	45	14.4%									
Missing	1	0.3%	Missing	17	5.4%	Missing	2	0.6	Missing	3	1.0
Total	313										

3. Results

3.1. Respondent Fishermen's demography

In total, 313 fishermen from thirteen fisheries were interviewed from September 2015 to August 2016, which achieved a sampling error of ± 5.5% within a 95% confidence level. All respondents were male. Ages ranged from 18 to 72. Approximately one third (31.0%) were 45–54 years old. More than forty percent (42.8%) had a junior high school degree. Seventy-two percent of respondents had more than 20 years of experience. Two hundred and sixty were captains (83.1%) (Table 2). Almost 90% depended on fisheries (88.2%) as their major income.

The vessels ranged from 0 to 500 GRT, of which 64.2% were small vessels. A total of 47.1% were line-type vessels, including pole and line (28%), bottom longline (10%), pelagic longline (8%), and other line types (1%). The other 53.0% were net-type vessels, including torch-light net (16%), trawler (15%), mackerel purse seiner (9%), gillnet (6%), crab pots (5%), and other nets (2%) (Fig. 4). Among the gear, most used pole and line, bottom longline, and gillnet on small vessels. In contrast, the torch-light, trawler, and Taiwanese purse seiners were mainly used on large vessels.

3.2. Perception of the threats to fishery resources

Among fourteen possible threats, respondents considered IUU fishing vessels from China (71.0%), overfishing (69.5%), and ghost fishing (64.0%) as the top three factors impacting marine resources.

The least important factors were introduced species (15.2%) and marine engineering (23.1%) (Table 3).

Percentages of groups that agreed and disagreed are shown in Table 3. Line fishermen and net fishermen have quite different attitudes about major threats. Line-type fishermen considered "marine debris" (75.5%), "ghost fishing" (72.6%), and "overfishing" (72.5%) to be major impacts. However, net fishermen did not. They considered "illegal Chinese fishing vessels" (73.3%) and "overfishing" (67.2%) to be the most serious impacts. In addition, line fishermen considered small mesh sizes (62.8%) to be a serious problem, but only half (33.0%) of net fishermen supported them. Net-type and large vessel fishermen both thought that inappropriate measures (60.5% and 71.2%) were problems, but there was a lower percentage of line-type and small vessel fishermen that thought this (44.2% and 44.4%). The differences between small vessel and large vessel fishermen were similar, since most line vessels were small vessels.

As for the difference between ages, the biggest differences between young and old fishermen were "climate change" (79.7% vs. 51.1%), "bycatch" (47.7% vs. 63.2%) and "introduced species" (6.7% vs. 19.4%). There were no statistically significant differences in other factors between younger and older fishermen.

3.3. Perceptions and attitudes toward the fisheries management measures

The degree of effectiveness, enforcement, and satisfaction of twelve measures are shown in Fig. 5. The means and differences between groups are listed in Table 4.

The enforcement of three net-regulation fisheries, including the gill
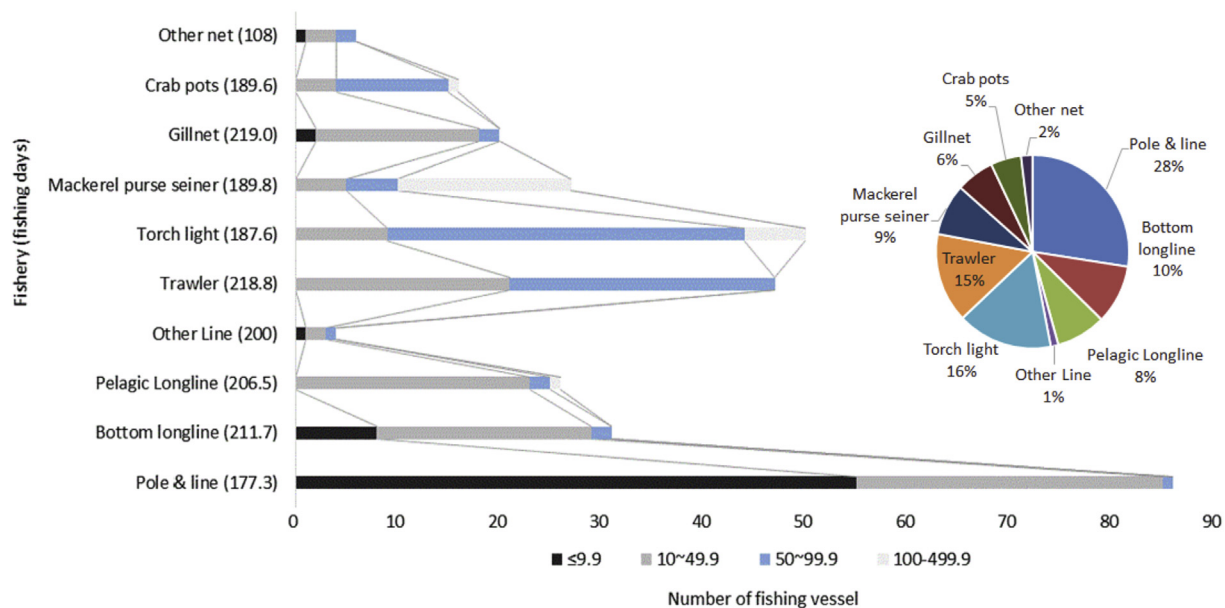
Fig. 4. Number of interviews' vessels by size and fisheries. Other line and net fisheries included hand and line, troll, flying fish roe fishery, larval anchovy, and precious corals fishery. The number in parentheses was the annual average number of fishing days.

Table 3
The agree percentage and differences among groups. The perception of reason may cause negative impact to fishing resources in different groups of fishermen. Statements were measured in a five-point Likert-scale, subsequently separated into disagree (1,2) and agree (=4,5); *: p < 0.05 (significant), **: p < 0.01 (highly significant); ***: p < 0.001 (extremely significant).

NO	Item	Agree %	Gear			Vessel Size			Age		
			Line	Net	P	Small	Large	p	Young	Old	p
1	Illegal Chinese fishing vessels	71.0	68.6%	73.3%	0.510	70.5%	72.2%	0.79	78.2%	68.4%	0.05
2	Overfishing	69.5	72.5%	67.2%	0.012*	74.0%	62.7%	0.12	70.5%	69.6%	0.001**
3	Ghost fishing	64.0	72.6%	55.6%	0.001***	71.7%	46.8%	0.001***	73.6%	60.1%	0.10
4	Marine debris	59.7	75.5%	45.4%	0.001***	68.8%	42.4%	0.001***	54.7%	62.0%	0.635
5	Climate change	59.3	52.5%	63.9%	0.494	57.6%	61.7%	0.73	79.7%	51.1%	0.001***
6	Bycatch	58.9	66.1%	50.9%	0.001***	61.7%	51.5%	0.28	47.7%	63.2%	0.001***
7	Habitat destruction	58.2	59.7%	56.9%	0.001**	55.8%	62.6%	0.03*	53.5%	60.2%	0.362
8	Lack of enforcement	56.9	61.3%	53.2%	0.215	59.8%	51.9%	0.71	61.6%	55.0%	0.594
9	Marine pollution	56.5	63.9%	50.8%	0.011*	60.7%	50.0%	0.001***	54.7%	57.7%	0.007*
10	Inappropriate measures	52,5	44.2%	60.5%	0.001***	44.4%	71.2%	0.001***	49.2%	53.4%	0.378
11	Small mesh size	45.3	62.8%	33.0%	0.001**	60.2%	23.4%	0.001***	48.2%	44.4%	0.07
12	Destructive fishing	44.5	50.7%	40.0%	0.075	51.4%	33.8%	0.001***	34.0%	49.%	0.459
13	Marine engineer	23.1	21.8%	24.0%	0.041*	21.0%	26.3%	0.001***	28.0%	21.6%	0.087
14	Introduced species	15.2	12.5%	18.2%	0.019*	14.1%	18.0%	0.11	6.7%	19.4%	0.004**

net, torch-light net, and trawlers were considered lower than others, which were no more than 20% in agreement. The gillnet was only 6.1% (strongly agree and agree). The satisfaction with gillnet (20.3%) and torch-light (33.7%) were also lower than for other fisheries. For the trawler fisheries closure-area, although the satisfaction is higher than the other two net fisheries (56.2%), the effectiveness was considered low (20.9%), and the enforcement was only 19.7% in terms of agreement. The effectiveness of trawlers was lower than the two net fisheries.

For shark fisheries, precious coral, and Taiwanese purse seiners, the enforcement was all over 50% in agreement, higher than net fisheries. However, effectiveness and satisfaction were only approximately 50%.

For those four conservation measures for juvenile and spawning stocks, effectiveness varied. The effectiveness score was highest for larval anchovy (50.0%) and lowest for flying fish roe (25.6%). The

enforcement was highest for eel fry fishery (65.3%) and lowest for crab fisheries (22.4%). The satisfaction was highest for eel fry fishery (54.1%) and was lowest for flying fish roe (16.5%). Among four fisheries, the larval anchovy fisheries management performance was better and the flying fish roe was the worst.

As for MPAs, more than 50% of interviewees showed a positive attitude toward the enforcement and satisfaction of the MPA regulations near their fishing ground; however, the effectiveness of MPAs was only 32.2%. There was high correspondence among the effectiveness, enforcement and satisfaction of VDR, at 49.3%, 58.5% and 56.6%. The enforcement of VDR indicated the VDR under normal usage.

The mean scores were further compared by group and are listed in Table 4. For the perception of effectiveness of regulations, the torch-light (3.73 ± 1.08), precious coral (3.57 ± 1.20) and gillnet
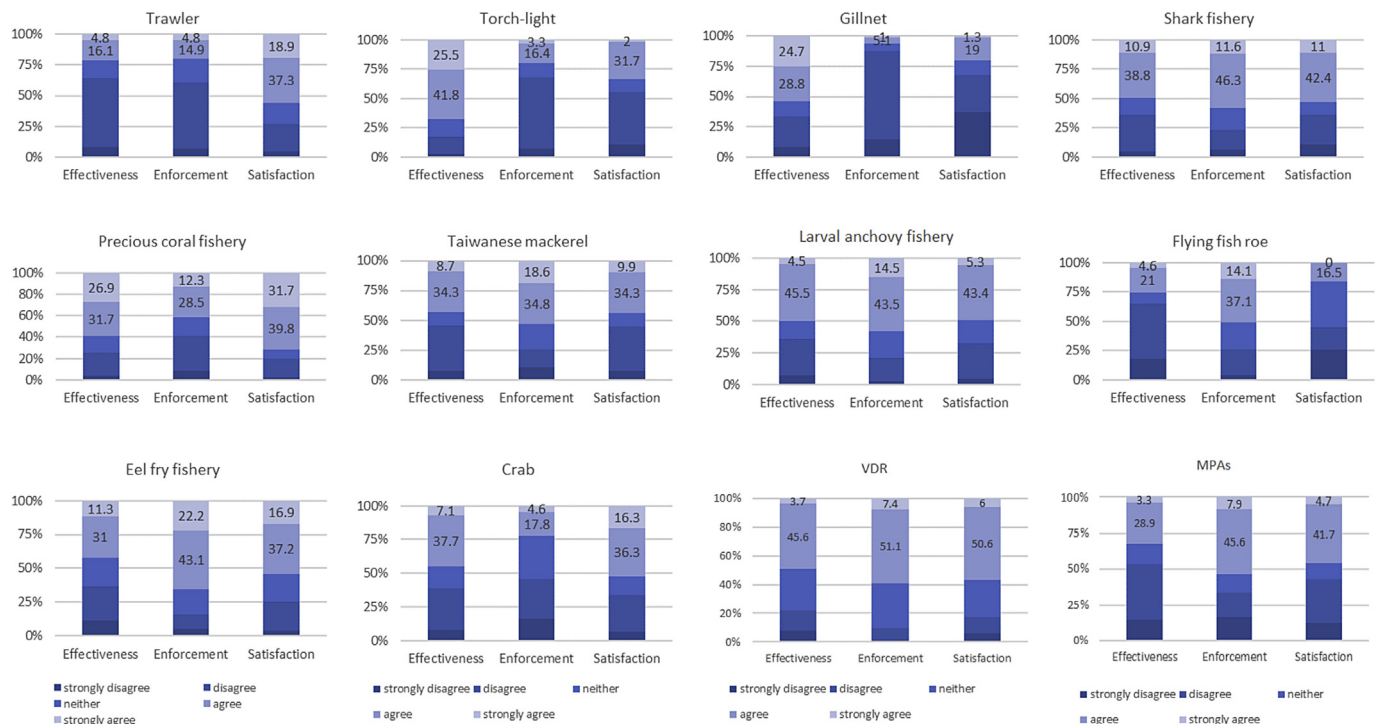
Fig. 5. Fishermen's perceptions on the effectiveness, enforcement and satisfaction of Taiwan coastal and offshore fishery management measures. The numbers in light colors are the percentage for each category. The darker color indicates "strongly agree" for each statement. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

Table 4
The mean score of effectiveness, enforcement and satisfaction of fisheries management measures and differences by group.

Type	Fisheries	Criteria	n	mean	sd	Gear type			Vessel size			Age		
						Line	Net	p	Small	Large	p	Young	Old	p
Net/area fisheries	Trawler	Effectiveness	230	2.54	1.01	2.47	2.62	0.431	2.51	2.60	0.301	2.48	2.55	0.105
		Enforcement	188	2.57	0.98	2.28	2.93	0.014	2.46	2.84	0.785	2.72	2.50	0.728
		Satisfaction	249	3.44	1.16	3.59	3.28	0.228	3.59	3.10	0.059	3.50	3.42	0.538
	Torch light regulation	Effectiveness	208	3.73	1.08	3.91	3.49	0.030	3.88	3.28	< 0.001	3.71	3.74	0.048
		Enforcement	213	2.48	0.96	2.33	3.40	< 0.001	2.39	2.72	< 0.001	2.72	2.36	< 0.001
		Satisfaction	202	2.69	1.09	2.46	2.97	0.002	2.59	2.95	0.030	2.78	2.65	0.130
	Gillnet limitation	Effectiveness	198	3.37	1.31	3.47	3.23	0.162	3.42	3.18	0.033	3.98	3.16	< 0.001
		Enforcement	197	2.05	0.71	1.98	2.13	0.002	2.01	2.20	0.001	2.17	2.00	0.096
		Satisfaction	158	2.16	1.16	2.00	2.39	0.182	2.10	2.35	0.375	2.37	2.10	0.133
Specific Stocks	Mackerel Purse Seiners	Effectiveness	230	2.98	1.18	3.02	2.94	0.562	2.84	3.34	0.780	2.74	3.09	0.120
		Enforcement	221	3.36	1.24	3.40	3.30	0.558	3.28	3.56	0.087	3.49	3.30	0.004
		Satisfaction	233	3.02	1.19	3.01	3.04	0.440	2.89	3.37	0.756	2.74	3.15	0.051
	Precious coral	Effectiveness	134	3.57	1.20	3.52	3.63	0.580	3.51	3.70	0.131	3.76	3.48	0.970
		Enforcement	124	3.39	3.73	3.48	3.28	0.311	3.44	3.24	0.561	3.21	3.46	0.436
		Satisfaction	152	3.18	1.23	3.71	3.93	0.002	3.75	3.98	0.009	3.94	3.75	0.432
	Shark conservation	Effectiveness	165	3.19	1.14	3.24	3.13	0.633	3.20	3.16	0.789	3.11	3.23	0.303
		Enforcement	147	3.40	1.09	3.30	3.55	0.001	3.42	3.35	0.070	3.41	3.40	0.898
		Satisfaction	172	3.18	1.23	3.12	3.27	0.047	3.18	3.18	0.231	3.21	3.17	0.640
Juvenile and spawning stock	Crab size regulation	Effectiveness	183	3.05	1.13	3.16	2.93	0.621	3.07	3.02	0.255	2.98	3.08	0.880
		Enforcement	152	2.64	1.09	2.58	2.72	0.613	2.52	2.95	0.989	2.28	2.76	0.751
		Satisfaction	190	3.50	1.22	3.45	3.08	0.250	3.35	3.10	0.236	3.17	3.32	0.733
	Eel fry limitation	Effectiveness	168	3.06	1.21	3.14	2.94	0.601	3.03	3.17	0.091	3.40	2.93	< 0.001
		Enforcement	144	3.67	1.09	3.58	3.78	0.626	3.65	3.74	0.136	3.53	3.71	0.228
		Satisfaction	172	3.42	1.12	3.40	2.37	0.036	3.42	3.41	0.006	3.61	3.34	0.001
	Flying fish roe regulation	Effectiveness	195	2.48	1.15	2.48	2.47	0.280	2.53	2.33	0.066	2.42	2.50	0.464
		Enforcement	170	3.35	1.10	3.26	3.49	0.272	3.31	3.52	0.232	3.35	3.35	0.104
		Satisfaction	194	3.46	1.05	3.66	3.23	0.559	3.52	3.29	0.400	3.43	3.48	0.010
	Larval anchovy regulation	Effectiveness	134	3.11	1.10	3.24	2.95	0.560	3.23	2.75	0.557	3.33	3.05	0.001
		Enforcement	124	3.49	1.03	3.60	3.35	0.863	3.54	3.33	0.811	3.61	3.47	0.022
		Satisfaction	152	3.16	1.05	3.20	3.12	0.656	3.20	3.05	0.580	3.30	3.11	0.119
General/ecosystem	VDR	Effectiveness	168	3.21	1.05	3.34	3.09	0.081	3.03	3.17	0.023	3.25	3.12	0.517
		Enforcement	144	3.57	0.98	3.60	3.55	0.012	3.54	3.63	0.935	3.59	3.55	0.372
		Satisfaction	172	3.39	1.00	3.51	3.27	0.046	3.46	3.26	0.202	3.24	3.46	0.442
	MPA	Effectiveness	165	2.68	1.14	2.61	2.74	0.556	2.67	2.70	0.500	2.68	2.65	0.062
		Enforcement	147	3.12	1.26	3.09	3.15	0.506	3.03	3.30	0.276	3.39	3.01	0.148
		Satisfaction	172	2.29	1.19	2.86	3.04	0.059	2.95	2.98	0.035	2.79	2.99	0.014

limitation (3.37 ± 1.31) were considered as the top three effective regulations. The regulation of flying fish roe (2.48 ± 1.15), trawler (2.54 ± 1.01), and MPA (2.29 ± 1.91) were the top three un-achievable regulations.

The highest enforcement was eel fry fishery (3.67 ± 1.09) and VDR (3.57 ± 0.98). Gillnet was the lowest score on compliance/enforcement, with a score of 2.05 (± 0.71).

The regulation of crab size, flying fish row and trawler were the top three satisfaction results with an average score of 3.50(± 1.22), 3.46(± 1.05) and 3.44 (± 1.16). The gillnet limitation (2.16 ± 1.16), MPA (2.29 ± 1.19) and torch-light regulation (2.69 ± 1.09) were the three measures with the most dissatisfaction.

Among different groups, line-type fishermen showed a negative confidence on trawler closures but gave high scores for effectiveness (2.28 and 3.59). On the other hand, the net fishermen felt stronger on enforcement (3.40) for torch-light regulation than line fishermen (2.33). Line fishermen were not satisfied with torch-light regulation (2.5) but believed regulations would be effective if followed with strict enforcement (3.91).

As for the difference between small-scale and large-scale fishermen, the small-scale fishermen gave relatively lower scores for enforcement on net fisheries (2.39 for torch-light fisheries and 2.01 for gillnet) compared to large vessel fishermen (2.72 for torch-light fisheries and 2.40 for gillnet).

Regarding the difference between ages, younger fishermen showed higher support for gillnet limitations (3.98 vs. 3.16) and effectiveness by eel fry fisheries (3.40 vs. 2.93).
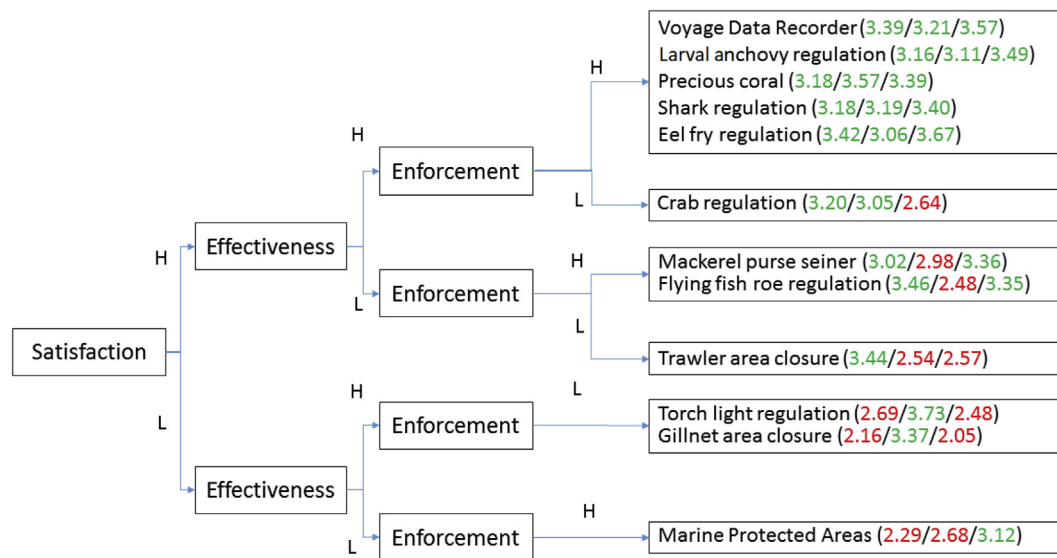
Satisfaction, effectiveness and enforcement are categorized in Fig. 6. Those measures could be separated into four groups. (A) A relatively higher score (mean > 3) for satisfaction, effectiveness and enforcement of coastal and offshore fishery management in Northern Taiwan for VDR, larval anchovy regulation, precious coral, shark conservation and eel fishery. (B) High satisfaction and effectiveness but low enforcement for crab size regulation. (C) The fisheries that received high satisfaction and enforcement but low effectiveness were mackerel purse seiners and flying fish roe regulation. (D) The trawl had high satisfaction but low effectiveness and enforcement. (E) The torch-light fishery regulation and gillnet had low satisfaction. (F) Low satisfaction and effectiveness for MPAs. Many fishermen considered these MPAs to be "a park on the paper" with poor regulations, publicity and enforcement.

3.4. General comments on fishery management

During the interview, more than half of fishermen expressed dissatisfaction about poor communication with policymakers. The fishermen said that the local government did convey the fishermen's advice on management policies through the fishermen's association, but they were skeptical about whether their perspectives were properly communicated between the local government and policy makers. Although there were public hearings before new regulations were set up, most fishermen were uncertain about trusting policies enacted due to their inability to frequently communicate with policymakers. At the same time, owners of small fishing boats believed that their voices were not counted in the industry, often resulting in the negative nature of their participation in relevant meetings.

Additionally, most fishermen were concerned about possible negative impacts if they offer detailed information to the government, such as the risk of taxation in the future and the risk of their secret fishing

Fig. 6. Fishermen's satisfaction, effectiveness and enforcement of Taiwan coastal and offshore fishery management measures. The value in the parentheses is the mean score for three categories. The green color indicates a score ≥3 and the red color indicates a score < 3. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

grounds being found out.

In terms of conflict, most fishermen believe that harmony within groups of fishermen is very important, so conflicts often occur between groups. For example, local fishermen were often dissatisfied with fishermen in other areas or in different fisheries. Fishermen groups often have friction with the government. They expect the government to regulate the source of the dispute in order to avoid conflict between the different fishery groups themselves.

Furthermore, most of interviewees agree that law enforcement is an effective means to curb illegal fishing practices. Legal implementation of fishing rules has improved in the past years, as observed by experienced fishermen, but more needs to be done to achieve the management goals. A contradictory attitude was found through the interview; on the one hand, fishermen expect appropriate regulations, but on the other hand, they have more interest in mitigating the effects of limitations forced by other fisheries than in developing their own.

4. Discussion

4.1. Lack of scientific assessment

Scientific research should be the base of management. During the review, it was found that only three of the measures have a data (logbook) submission requirement, including flying fish roe, precious corals, and larval anchovy. Most fisheries are data-poor.

Among those resources assessed, the scientists provided some conservation suggestions. For example, closures should be implemented 3 nm from Penchia Islet in March and April to conserve the swordtail squid resources (Huang et al., 2016). The fishing efforts for mackerel should be reduced (Chen et al., 2016; Lee et al., 2013; Lu, 2015). Huang and Liu (2013) suggested that shark management should be improved to conserve scalloped hammerhead shark. However, most of the abovementioned suggestions were not taken into consideration for management measures.

As for those fisheries managed with TAC, the results showed that the catches were still low and mostly lower than TAC. During the interviews, some fishermen described the time closure as "turn off the air conditioner during the winter", which implies the time closure is set in the low fishing season, which is not effective for conservation. In general, a lack of scientific based regulations or periodic review were reasons for fishermen to distrust regulations.

4.2. Main threats to Taiwan coastal resources

In the view of Taiwanese fishermen, the major threats are "IUU fishing" and "irresponsible fishing behavior". During the interview, many fishermen emphasized the importance of law enforcement. The poor monitoring, control system, and law enforcement were reflected by fishermen, particularly regarding the transboundary IUU fishing vessel from China and the trawler 3 nm closed area. The Fisheries Agency (FA) lacks enforcement power and mostly depends on the Coast Guard Administration (CGA), which has other concurrent missions such as enforcement for smuggling. There were 166 cases of illegal Chinese vessels caught by CGA in northeast waters in 2015. Other IUU cases included illegally poisoning fish or using explosives or electric shock (30%; 61 cases) (Coast Guard Administration, 2016). The success is likely to depend on proper enforcement and reliable governance (Foster and Vincent, 2010).

Ghost fishing, marine debris, and marine pollution are also troublesome. Line-type fishermen have stronger concerns about ghost fishing issues than net-type fishermen. It is possible that the source of those problems is caused by derelict gears. There are limited regulations and enforcements for fishing vessels waste control. More strong actions and regulations, such as a ban on garbage disposal at sea and plastic-limited regulations, are necessary. Education should be strengthened for net-type fishermen.

4.3. Fishermen's attitudes toward the management measures

As shown in Fig. 6, five fisheries received stricter monitoring compared with other fisheries. However, although eel fry fishery regulation received the highest score of satisfaction (3.42) and enforcement (3.67), effectiveness scored lower (3.09). They gave the high score simply due to its convenience.

Although the fishermen understood the port inspection efforts on the part of CGA, some fishermen thought the enforcement of crab fisheries was not enough because there are ways to escape enforcement. These include illegal transshipping of undersize or egg-carrying female crabs to China's fishing vessels or taking the eggs of female crabs at sea (Lin, 2013a,b).

Mackerel purse seiner regulation was perceived reasonable but its management ineffective due to the high capacity of the fishery. Although the catch continued increasing, the size decreased. A season-

only closure is not enough. TAC or capacity limitation are needed.

Low enforcement was also observed in trawler fishery closure areas and caused low effectiveness (Lin, 2014). Many line-type and torch-light fishermen suggested to expand the current 3 miles closed area due to the impacts of trawlers. Considering that there are more than 1000 trawlers within such small areas, capacity management should be considered.

Torch-light regulation was complained about due to loose limitation on the kilowatts of the fish attracting lamp (Wong, 2017). Despite the fishery authority formulating an administrative principle, regulations among different local governments varied, which resulted in confusion.

For gillnet fishery, during the interview, line-type fishermen complained of its potential risks from ghost fishing (Bellido et al., 2011). Fishermen believed that if the regulation was strictly followed, results could be achieved.

Different attitudes regarding the current marine resource issues by groups of fishermen were found in this research. Young fishermen are concerned about "climate change" more due to higher educational level, and older fishermen consider that temperature change is cyclical (Zhang et al., 2012). The line-type fishermen are concerned about marine debris, ghost fishing and small mesh size sourced from net-fisheries.

Although not all items show significant differences, lower satisfaction with effectiveness and enforcement were found for line-type, small size and older fishermen. This result is different from the study on the northeastern Brazilian coast, where younger fishermen have a more conservationist perspective (Shiau et al., 2014). In Taiwan, older fishermen have positive attitudes toward fishery resource conservation due to having previously seen rich fisheries resources, and they show more of an understanding of the trend of overfishing and agree that action to conserve resources is necessary.

Additionally, the standards of regulations for different fisheries brought fishery groups into conflict. The perception of sustainable development policies was discussed for reducing the conflict among stakeholders and to help improve the policy (Reilly et al., 2015). A successful conservation measure is often predicated on the support from stakeholders, experiments by local communities and opinions of management and governance (Bennett and Dearden, 2014). The main reason is that the decision-makers rely on work from scientists, who mostly focus on studies of a single species. Contrarily, fishing is based on the information from their daily lives at sea and emphasizes complexity and interconnectedness (Verweij and van Densen, 2010). Since fisheries management is a multiplayer game, it is hard to achieve sustainable goals by relying solely on single species management (Arkema et al., 2006).

5. Conclusion

In summary, the following suggestions are proposed to conserve the coastal marine resources for Taiwan.

First, data collection, scientific research and a review system should be established. Those coastal and offshore fishery regulations of Taiwan were established in a decade. Some research on the effectiveness of management measures was just shown in Taiwanese mackerel purse seiner (Chen et al., 2016; Lee et al., 2013; Lu, 2015) and flying fish roe fisheries (Chen et al., 2016; Huang et al., 2016). However, many other fisheries resources, including an ecosystem approach, were very limited. The effectiveness of MPA was low or not proved, therefore we can neither support or rejects its efficacy (Wen and Chen, 2014). A comprehensive research program would be the base for conservation. The VMS and observer system should be applied to coastal and offshore fisheries to ensure data collection and compliance. Fishermen might hesitate to provide catch information because they do not want others to know their fishing grounds and are afraid of being charged the tax. However, when fishery resource disasters are caused by oil spills from shipping accidents, the compensation for the damage is hard to

estimate due to the lack of a long-term social-economic dataset (Chen, 2016), such as whether such an event could be used as promotion to build willingness in fishermen to provide more complete information.

Second, this research found that "IUU fishing" and "irresponsible fishing behavior" are the strongest concerns to Taiwanese fishermen. Strengthening the enforcement and reviewing the relative regulations and policy are necessary. Previously, the priority of CGA was smuggling and drugs. Since 2016, the government decided to take more action on fisheries enforcement and build new patrol boats, which are expected to increase enforcement ability. For illegal Chinese fishing vessels, CGA decided to take stronger action in 2016, including increasing the fine or scrapping the vessels. The number of Chinese vessels has seemed to decrease recently. On the other hand, the fine ranged from $ 1000–5000, which was low compared to the potential illegal benefits. This law should be revised to increase the fine. Otherwise, some fishermen will engage in illegal fishing due to the low risk.

Third, promoting public awareness of marine conservation is one important approach to get support for the sustainable management of marine resources. Community-based and co-management have been a great way to establish the success of fishery management systems (Pomeroy et al., 2001). Cooperation between industry, government, and scientists (Field et al., 2013) or the consideration of human welfare (Mahajan and Daw, 2016) would help to improve sustainability and facilitate responsible fisheries. Moreover, the other concerns of fishermen, such as marine debris, marine pollution and climate change, cannot be separated from the individual. The responsibility to promote public awareness of marine conservation is not just for the government but also for NGOs and the media.

Finally, Taiwan has gradually emphasized ecosystem-based fishery management (EBFM) in recent years (Shao, 2009). However, because the current data available are single-species data, perception gaps are created when the emphasis on EBFM broadens the management to the ecosystem-level and incorporates the effect of human behavior and interaction. To address these perception gaps, this research recommends improving mutual communication among policymakers and fishers, enabling better understanding of the management measures among fishermen and providing policymaker feedback of reasonable means for its implementation.

It is hard to achieve sustainable fishery resources in a simple way. The policymaker should take a macroscopic view of the issue that fishermen are concerned about, including IUU fishing, ghost fishing and marine pollution. The most important thing is the communication and cooperation among policy makers, local government, resource users and enforcement authority. Resources and capacity for management, including data collection, policy sharing and information transparency, should be integrated. Policy and regulation should be publicized to fishermen, and the public awareness of the importance of sustainable resources and environment should be raised. In the end, fishery management should integrate biological and social (economic) issues.

Acknowledgements

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ocecoaman.2019.01.015.

References

Agnew, D.J., Pearce, J., Pramod, G., Peatman, T., Watson, R., Beddington, J.R., Pitcher, T.J., 2009. Estimating the worldwide extent of illegal fishing. PLoS One 4, e4570.
Arkema, K.K., Abramson, S.C., Dewsbury, B.M., 2006. Marine ecosystem-based

management: from characterization to implementation. Front. Ecol. Environ. 4, 525–532.

Baulch, S., Perry, C., 2014. Evaluating the impacts of marine debris on cetaceans. Mar. Pollut. Bull. 80, 210–221.

Bax, N., Williamson, A., Aguero, M., Gonzalez, E., Geeves, W., 2003. Marine invasive alien species: a threat to global biodiversity. Mar. Policy 27, 313–323.

Bellido, J.M., Santos, M.B., Pennino, M.G., Valeiras, X., Pierce, G.J., 2011. Fishery discards and bycatch: solutions for an ecosystem approach to fisheries management? Hydrobiologia 670, 317.

Bennett, N.J., Dearden, P., 2014. Why local people do not support conservation: community perceptions of marine protected area livelihood impacts, governance and management in Thailand. Mar. Policy 44, 107–116.

Bilkovic, D.M., Havens, K., Stanhope, D., Angstadt, K., 2014. Derelict fishing gear in Chesapeake Bay, Virginia: spatial patterns and implications for marine fauna. Mar. Pollut. Bull. 80, 114–123.

Bruckmeier, K., Ellegård, A., Píriz, L., 2005. Fishermen's interests and cooperation: preconditions for joint management of Swedish coastal fisheries. AMBIO A J. Hum. Environ. 34, 101–110.

Chang, S.-K., 2011. Application of a vessel monitoring system to advance sustainable fisheries management—benefits received in Taiwan. Mar. Policy 35, 116–121.

Chen, C.-L., 2010. Factors influencing participation of 'top-down but voluntary' fishery management—empirical evidence from Taiwan. Mar. Policy 34, 150–155.

Chen, C.-S., 2012. Management of the precious coral fishery in Taiwan: progress and perspectives. Mar. Policy 36, 623–629.

Chen, W.-H., 2016. Fishermen Demand Help on Oil Spill. Taipei Times, Taipei.

Chen, K.-Y., Chiu, T.S., Tzeng, T.-D., Chen, K.S., Chen, C.-S., Jeng, M.-S., 2016. Investigation on Major Fishery Resources and Studies on Reasonable Regulatory Devices in the Coastal Water of Taiwan Taipei.

Coast Guard Administration, 2016. Coast guard annual statistical report. In: Administration, C.G. (Ed.), Taipei: Coast Guard Administration, Executive Yuan.

Coleman, F.C., Williams, S.L., 2002. Overexploiting marine ecosystem engineers: potential consequences for biodiversity. Trends Ecol. Evol. 17, 40–44.

Council of Agriculture, 1999. The Closure Areas and Related Limitation for Trawler.

Council of Agriculture, 2007. Regulations for the Installation and Maintains of Voyage Data Recorder.

CPAMI, 2008. The Meeting of Feasibility Assessment of Northern Three Islet Marine National Park. Taipei. Taipei. The Construction and Planning Agency, Ministry of Interior.

Davies, R.W.D., Cripps, S.J., Nickson, A., Porter, G., 2009. Defining and estimating global marine fisheries bycatch. Mar. Policy 33, 661–672.

Dimech, M., Darmanin, M., Smith, I.P., Kaiser, M.J., Schembri, P.J., 2009. Fishers' perception of a 35-year old exclusive fisheries management zone. Biol. Conserv. 142, 2691–2702.

FAO, 2016. The State of World Fisheries and Aquaculture. Food and Agriculture Organization of the United Nations, Rome.

Field, J., Attwood, C., Jarre, A., Sink, K., Atkinson, L., Petersen, S., 2013. Cooperation between scientists, NGOs and industry in support of sustainable fisheries: the South African hake Merluccius spp. trawl fishery experience. J. Fish. Biol. 83, 1019–1034.

Fisheries Agency, 2002. Voluntary Suspension of Fishing Activities Award Guidelines. Fishery Agency.

Fisheries Agency, 2014. Coastal Crab Fishery Management Measure.

Fisheries Agency, 2016. Annual Report of Fisheries Agency. Fisheries Agency, Council of Agriculture, Executive Yuan, Taipei, Taiwan.

Fisheries Agency, 2016. Coastal Water Fisheries Management and Practice of Responsible Fisheries. Fishery Agency.

Fisheries Agency, 2018. Fisheries Statistical Yearbook 2017, Taiwan, Kinmen and Matsu Area. Fisheries Agency, Council of Agriculture, Executive Yuan, Taipei, Taiwan.

Foster, S.J., Vincent, A.C.J., 2010. Tropical shrimp trawl fisheries: Fishers' knowledge of and attitudes about a doomed fishery. Mar. Policy 34, 437–446.

Garza-Gil, M.D., Amigo-Dobaño, L., Surís-Regueiro, J.C., Varela-Lafuente, M., 2015. Perceptions on incentives for compliance with regulation. The case of Spanish fishermen in the Atlantic. Fish. Res. 170, 30–38.

Gelcich, S., Godoy, N., Castilla, J.C., 2009. Artisanal Fishers' perceptions regarding coastal co-management policies in Chile and their potentials to scale-up marine biodiversity conservation. Ocean Coast Manag. 52, 424–432.

Goodman, L.A., 2011. Comment: on respondent-driven sampling and snowball sampling in hard-to-reach populations and snowball sampling not in hard-to-reach populations. Socio. Methodol. 41, 347–353.

Hoegh-Guldberg, O., Mumby, P.J., Hooten, A.J., Steneck, R.S., Greenfield, P., Gomez, E., Harvell, C.D., Sale, P.F., Edwards, A.J., Caldeira, K., 2007. Coral reefs under rapid climate change and ocean acidification. Science 318, 1737–1742.

Hong, S., Lee, J., Jang, Y.C., Kim, Y.J., Kim, H.J., Han, D., Hong, S.H., Kang, D., Shim, W.J., 2013. Impacts of marine debris on wild animals in the coastal area of Korea. Mar. Pollut. Bull. 66, 117–124.

Huang, M.-H., Ou, C.-H., 2010. 2010. Precious coral fisheries management in Taiwan-Past, present & future. Mar. Policy 34, 1002–1009.

Huang, H.-W., Chuang, C.-T., 2010. Fishing capacity management in Taiwan: experiences and prospects. Mar. Policy 34, 70–76.

Huang, H.-W., Wang, S.-B., Wang, S.-P., Lu, H.-J., Chen, C.-S., Liao, C.-H., Liu, K.-M., Su, N.-J., 2016. Status and Challenges for Taiwan Marine Fisheries Resources, the 4th Taiwan and Ocean Conference. National Taiwan Ocean University & Taiwan Research Foundation, Taipei.

Huang, L.-H., Liu, K.-M., 2013. Assessment of the Impact on Pelagic Species by Taiwanese Offshore Longline Fishery in the Northwest Pacific Using an Integrated Ecological Risk Assessment. Institute of Marine Affairs and Resource Management. Keelung: National Taiwan Ocean University.

Huang, M.-H., Ou, C.-H., 2012. A discussion of management disputes arising from the multiple utilization of flying fish resources in Taiwan and suggested countermeasures. Mar. Policy 36, 512–519.

Jagers, S.C., Berlin, D., Jentoft, S., 2012. Why comply? Attitudes towards harvest regulations among Swedish Fishers. Mar. Policy 36, 969–976.

Karper, M.A.M., Lopes, P.F.M., 2014. Punishment and compliance: exploring scenarios to improve the legitimacy of small-scale fisheries management rules on the Brazilian coast. Mar. Policy 44, 457–464.

Kumar, A.B., Deepthi, G., 2006. Trawling and by-catch: implications on marine ecosystem. Curr. Sci. 90, 922–931.

Lee, C.-L., Wu, S.-H., Wang, Y.-C., Tseng, C.-D., 2006. The mackerel fishery in Taiwan. FRI Newslett. 13.

Lee, K.-T., Wei, L.-Y., Lee, M.-A., 2013. A preliminary studies on the reproductive biology of the Scomber australasicus in the northeastern waters off Taiwan. In: Taiwan Offshore Fishery Management-Fishery Species Scientific Research Conference. Keelung: National Taiwan Ocean University.

Leleu, K., Alban, F., Pelletier, D., Charbonnel, E., Letourneur, Y., Boudouresque, C.F., 2012. Fishers' perceptions as indicators of the performance of Marine Protected Areas (MPAs). Mar. Policy 36, 414–422.

Lin, Y.-K., 2013a. Crab Fishery Management Measure, a Test of Enforcement. Fishery and aquaculture. News & Market, Taipei.

Lin, Y.-K., 2013b. The Legislator and Fishery Agency Are Not on the Same Page of the Regulation of the Mackerel Purse Seiner. Fishery and Aquiculture. News & Market, Taipei.

Lin, Y.-K., 2014. Local Communities Don't Reach a Consensus on Trawl Fishery Closure Areas. Fishery and Aquaculture. News & Market, Taipei.

Liu, K.-M., 2015. A review of shark conservation and management in Taiwan. In: 2014 International Conference on Animal Liberation, Animal Rights, and Equal Ecological Rights: Dialogues between Eastern and Western Philosophy and Religions.

Lockwood, M., 2010. Good governance for terrestrial protected areas: a framework, principles and performance outcomes. J. Environ. Manag. 91, 754–766.

Lu, H.-J., 2015. Assessment of Mackerel and Scad Fishery Resources in the Waters of Taiwan. National Taiwan Ocean University, Taipei.

Mahajan, S.L., Daw, T., 2016. Perceptions of ecosystem services and benefits to human well-being from community-based marine protected areas in Kenya. Mar. Policy 74, 108–119.

Pérez-Sánchez, E., Muir, J.F., 2003. Fishermen perception on resources management and aquaculture development in the Mecoacan estuary, Tabasco, Mexico. Ocean Coast Manag. 46, 681–700.

Parsons, E., Favaro, B., Aguirre, A.A., Bauer, A.L., Blight, L.K., Cigliano, J.A., Coleman, M.A., Cote, I.M., Draheim, M., Fletcher, S., 2014. Seventy-one important questions for the conservation of marine biodiversity. Conserv. Biol. 28, 1206–1214.

Pierce, B., Mozumder, P., 2014. Perceptions and preferences of commercial Fishers for dedicated access privilege framework in a multispecies fishery. Mar. Policy 45, 52–59.

Pita, C., Pierce, G.J., Theodossiou, I., 2010. Stakeholders' participation in the fisheries management decision-making process: Fishers' perceptions of participation. Mar. Policy 34, 1093–1102.

Pomeroy, R.S., Katon, B.M., Harkes, I., 2001. Conditions affecting the success of fisheries co-management: lessons from Asia. Mar. Policy 25, 197–208.

Reilly, K., O'Hagan, A.M., Dalton, G., 2015. Attitudes and perceptions of fishermen on the island of Ireland towards the development of marine renewable energy projects. Mar. Policy 58, 88–97.

Rodwell, L.D., Lowther, J., Hunter, C., Mangi, S.C., 2014. Fisheries co-management in a new era of marine policy in the UK: a preliminary assessment of stakeholder perceptions. Mar. Policy 45, 279–286.

Shahidul Islam, M., Tanaka, M., 2004. Impacts of pollution on coastal and marine ecosystems including coastal and marine fisheries and approach for management: a review and synthesis. Mar. Pollut. Bull. 48, 624–649.

Shiau, C.-Y., Wang, C.-H., Liu, P.-C., Miao, S., Han, Y.-S., Lee, K.-K., Huang, Z.-T., Liu, C.-S., Nan, F.-H., 2014. The Study on Resource Restoration of Eel Taipei.

Shao, K.-T., 2009. Marine biodiversity and fishery sustainability. Asia Pac. J. Clin. Nutr. 18, 527–531.

Shu, C.-J., 2014. Fishermen Protest the Closure-Area Measure of Trawler. Chinatime. Pintong.

Silva, M.R.O., Lopes, P.F.M., 2015. Each fisherman is different: taking the environmental perception of small-scale fishermen into account to manage marine protected areas. Mar. Policy 51, 347–355.

Silvano, R.A., Valbo-Jørgensen, J., 2008. Beyond fishermen's tales: contributions of Fishers' local ecological knowledge to fish ecology and fisheries management. Environ. Dev. Sustain. 10, 657.

Suman, D., Shivlani, M., Walter Milon, J., 1999. Perceptions and attitudes regarding marine reserves: a comparison of stakeholder groups in the Florida Keys National Marine Sanctuary. Ocean Coast Manag. 42, 1019–1040.

Tacon, A.G., Metian, M., 2008. Global overview on the use of fish meal and fish oil in industrially compounded aquafeeds: trends and future prospects. Aquaculture 285, 146–158.

Tzeng, T.-D., 2015. Survey and Assessment and Reproductive Biology for Crab Fisheries Resources in North of the Taiwan Strait and off Penghu. Taipei.

Verweij, M.C., van Densen, W.L.T., 2010. Differences in causal reasoning about resource dynamics and consequences for the participatory debate on North Sea fisheries. Mar. Policy 34, 1144–1155.

Villasante, S., Pierce, G.J., Pita, C., Guimeráns, C.P., Garcia Rodrigues, J., Antelo, M., Da Rocha, J.M., Cutrín, J.G., Hastie, L.C., Veiga, P., Sumaila, U.R., Coll, M., 2016. Fishers' perceptions about the EU discards policy and its economic impact on small-scale fisheries in Galicia (North West Spain). Ecol. Econ. 130, 130–138.

Wang, K.-Y., Liao, C.-H., Lee, K.-T., 2008. Population and maturation dynamics of the swordtip squid (Photololigo edulis) in the southern East China Sea. Fish. Res. 90, 178–186.

Wen, C.K.-C., Chen, C.A., 2014. The sustainable coral reef fishery of marine protected areas and a brief review of marine protected area studies in Taiwan. J. Natl. Park 24, 78–87.

Wong, J.-W., 2017. Torch-light Fishing Boats Have Been Seized Repeatedly Violate Limitation on Kilowatts of the Fish-Attracting Lamp. Taiwan People News. Taiwan People News, Hualien.

Zhang, J., Fleming, J., Goericke, R., 2012. Fishermen's perspectives on climate variability. Mar. Policy 36, 466–472.